US009302185B2

(12) **United States Patent**
Dawson et al.

(10) **Patent No.: US 9,302,185 B2**
(45) **Date of Patent: Apr. 5, 2016**

(54) **DECISION STREAMS FOR SYNCHRONIZING VISUAL SCRIPT LANGUAGE PROCESSING BETWEEN NETWORKED COMPUTERS**

(75) Inventors: **Matthew Dawson**, Highland, UT (US); **Phil Knight**, Stansbury Park, UT (US); **Kirk Baum**, American Fork, UT (US)

(73) Assignee: **Disney Enterprises, Inc.**, Burbank, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 190 days.

(21) Appl. No.: **13/523,084**

(22) Filed: **Jun. 14, 2012**

(65) **Prior Publication Data**

US 2013/0339421 A1 Dec. 19, 2013

(51) **Int. Cl.**

G06F 15/16	(2006.01)
A63F 13/47	(2014.01)
H04N 21/478	(2011.01)
A63F 13/60	(2014.01)
A63F 13/358	(2014.01)

(52) **U.S. Cl.**

CPC ***A63F 13/47*** (2014.09); ***A63F 13/358*** (2014.09); ***A63F 13/60*** (2014.09); ***H04N 21/4781*** (2013.01); *A63F 2300/5533* (2013.01); *A63F 2300/5573* (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,774,668	A *	6/1998	Choquier	G06F 9/505 370/480
5,838,909	A *	11/1998	Roy et al.	709/209
5,898,834	A *	4/1999	Sharpe	H04L 29/06 709/201
6,415,317	B1 *	7/2002	Yelon et al.	709/205
6,742,028	B1 *	5/2004	Wang	G06F 17/30209 707/999.01
6,763,377	B1 *	7/2004	Belknap	H04L 29/06027 709/223
6,957,266	B2 *	10/2005	Evans	H04N 21/2368 348/500
7,174,361	B1 *	2/2007	Paas	709/203
7,363,431	B1 *	4/2008	Niver	H04L 67/1095 707/999.201
7,661,109	B2 *	2/2010	Lindhorst et al.	719/316
8,244,804	B1 *	8/2012	Casselman	709/203
8,449,397	B2 *	5/2013	Martone	463/42
2002/0160833	A1 *	10/2002	Lloyd	A63F 13/10 463/29
2005/0149481	A1 *	7/2005	Hesselink et al.	707/1
2006/0235547	A1 *	10/2006	Hindi	G03G 15/50 700/2

(Continued)

OTHER PUBLICATIONS

Bishop, Lars, et al. "Designing a PC game engine." Computer Graphics and Applications, IEEE 18.1 (1998): 46-53.*

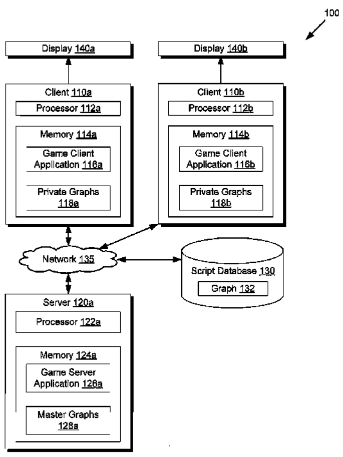
(Continued)

Primary Examiner — Scott B Christensen
Assistant Examiner — Lam Do
(74) *Attorney, Agent, or Firm* — Farjami & Farjami LLP

(57) **ABSTRACT**

A method is provided for decision streams for synchronizing visual script language processing between networked computers. A master computing device may receive a remote kickoff stream indicating master nodes to be processed on a master graph, create a master decision stream using the remote kickoff stream, process master nodes of the master graph to populate the master decision stream with states and actions during the processing, and distribute the master decision stream to clients for synchronization of private graphs. The master and private graphs may be copies of the same visual script for implementing game logic, which may be created and edited using a graphical user interface (GUI). Nodes of the graphs can be marked as master, requiring global synchronization, or private, allowing immediate local processing with reduced latency. Thus, online game designers are empowered to balance the competing concerns of state synchronization and latency.

20 Claims, 6 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2007/0022122	A1*	1/2007	Bahar	G06F 9/5011
2009/0254843	A1*	10/2009	Van Wie	H04L 12/1822 715/757
2012/0016904	A1*	1/2012	Mahajan	G06F 17/30575 707/769
2012/0166516	A1*	6/2012	Simmons et al.	709/202
2012/0233418	A1*	9/2012	Barton	G06F 17/30575 711/162
2012/0330887	A1*	12/2012	Young et al.	707/610
2013/0059664	A1*	3/2013	Behmaram-Mosavat	A63F 13/12 463/42

OTHER PUBLICATIONS

White, Walker et al. “Better scripts, better games.” Communications of the ACM 52.3 (2009): 42-47.*

Ploss, Alexander, et al. “From a single-to multi-server online game: a Quake 3 case study using RTF.” Proceedings of the 2008 International Conference on Advances in Computer Entertainment Technology. ACM, 2008.*

J. M. P. V. Waveren, “The Quake III Arena Bot,” Master’s thesis, University of Technology Delrt, Netherlands, 2001.*

Perez, Diego, et al. “Evolving behavior trees for the Mario AI competition using grammatical evolution.” Applications of Evolutionary Computation. Springer Berlin Heidelberg, 2011. 123-132.*

Caltagirone, Sergio, et al. “Architecture for a massively multiplayer online role playing game engine.” Journal of Computing Sciences in Colleges 18(2) (2002): 105-116.*

Hampel, Thorsten, Thomas Bopp, and Robert Hinn. “A peer-to-peer architecture for massive multiplayer online games.” Proceedings of 5th ACM SIGCOMM workshop on Network and system support for games. ACM, 2006.*

Cronin, Eric, et al. “An efficient synchronization mechanism for mirrored game architectures.” Multimedia Tools and Applications 23.1 (2004): 7-30.*

Gill, Sunbir, “Visual Finite State Machine AI Systems.” Gamasutra (Nov. 2004), http://www.gamasutra.com/features/20041118/gill-01.shtml.*

Kienzle, Jorg, Alexandre Denault, and Hans Vangheluwe. “Model-Based Design of Computer-Controlled Game Character Behavior.” Model Driven Engineering Languages and Systems. Springer Berlin Heidelburg, 2007. 650-665.*

Lewis, Michael, and Jeffery Jacobson. “Game Engines.” Communications of the ACM 45.1 (2002): 27.*

Claypool, Mark, and Kajal Claypool. “Latency and player actions in online games.” Communications of the ACM 49.11 (2006): 40-45.*

Grabska-Gradzińska, Iwona, et al. “Towards a Graph-Based Model of Computer Games.” (2012).*

Mens, Tom, Gabriele Taentzer, and Olga Runge. “Analysing refactoring dependencies using graph transformation.” Software & Systems Modeling 6.3 (2007): 269-285.*

* cited by examiner

Fig. 1

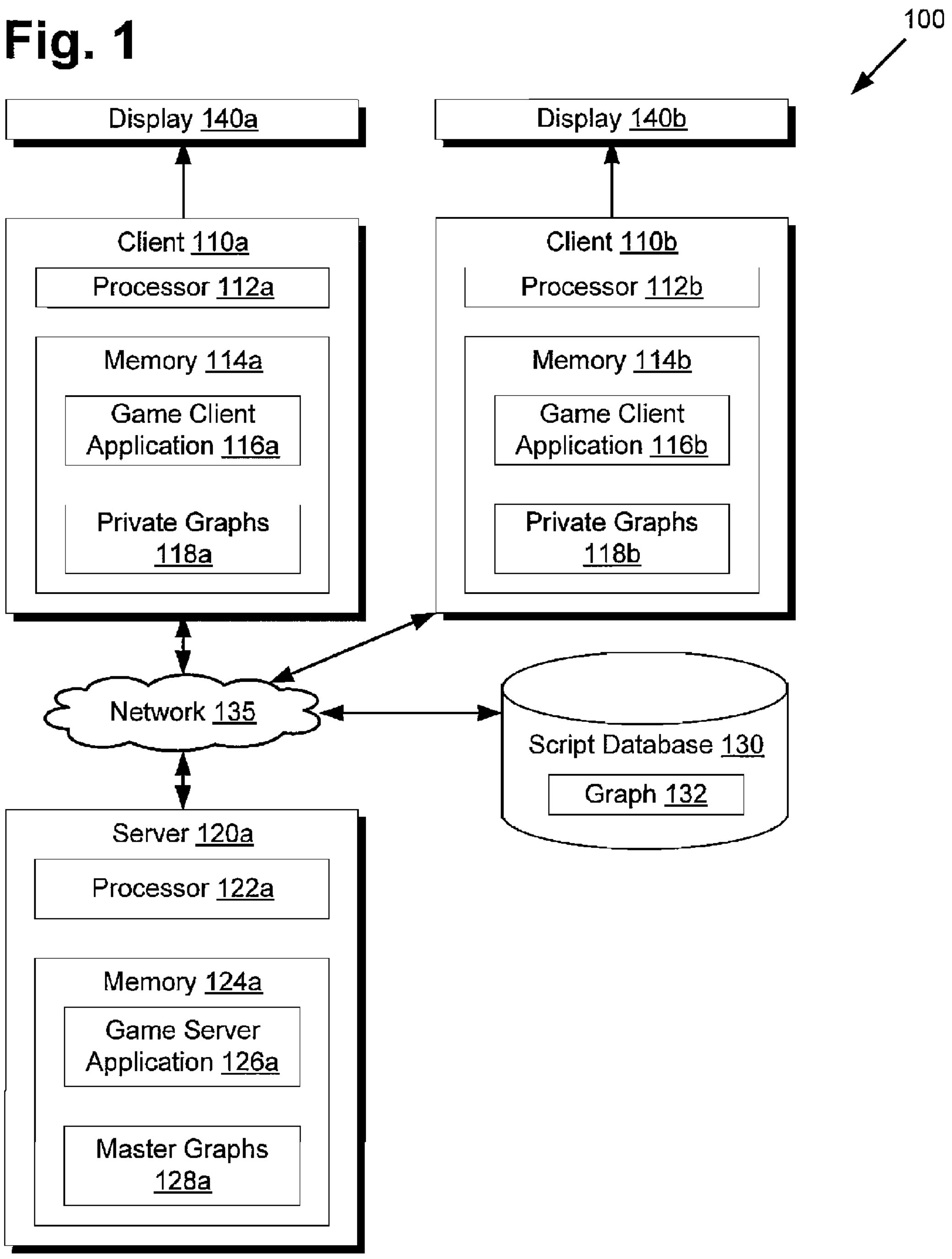

100
Display 140a
Display 140b
Client 110a
Processor 112a
Memory 114a
Game Client Application 116a
Private Graphs 118a
Client 110b
Processor 112b
Memory 114b
Game Client Application 116b
Private Graphs 118b
Network 135
Script Database 130
Graph 132
Server 120a
Processor 122a
Memory 124a
Game Server Application 126a
Master Graphs 128a

Fig. 2A

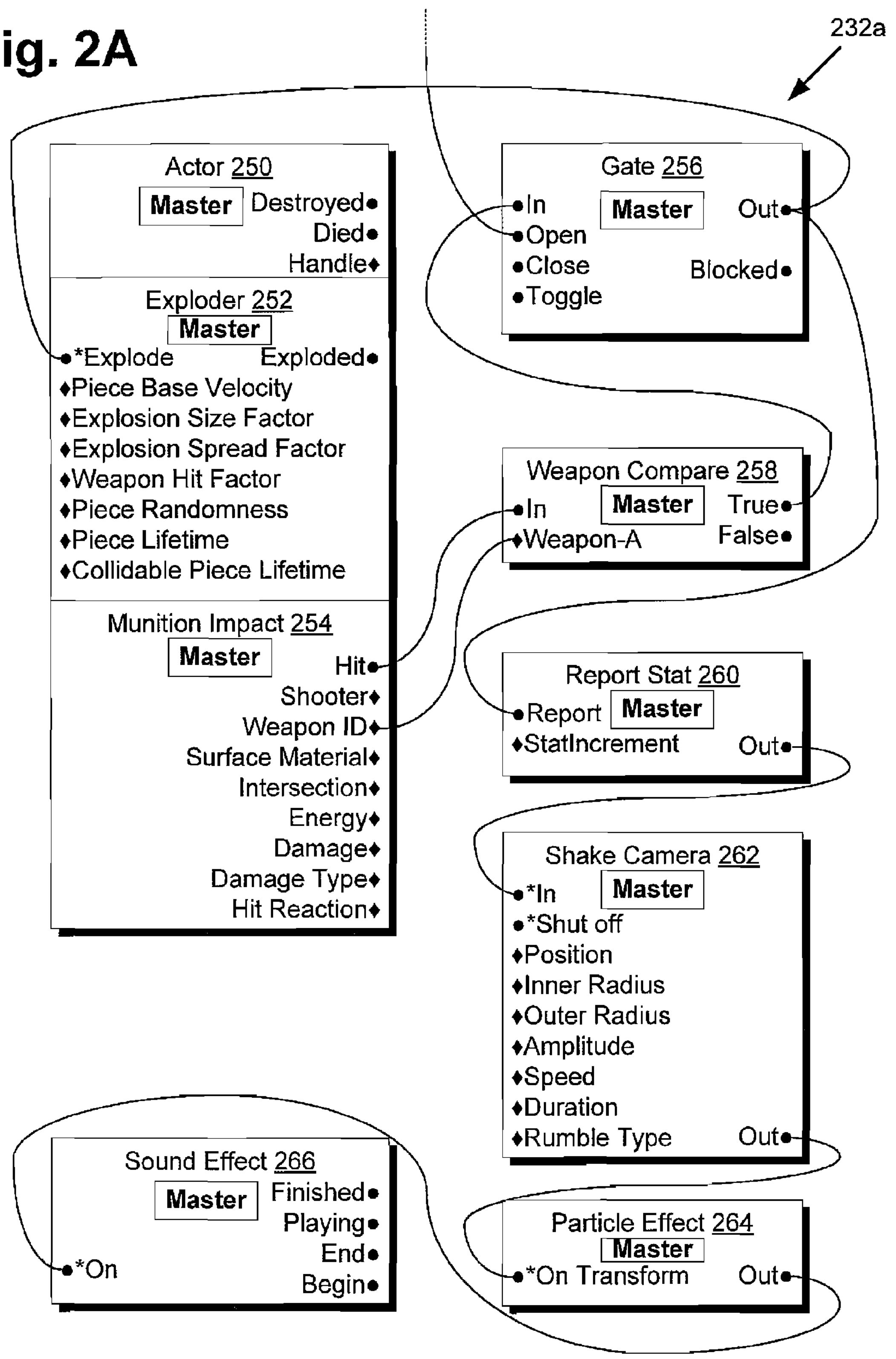
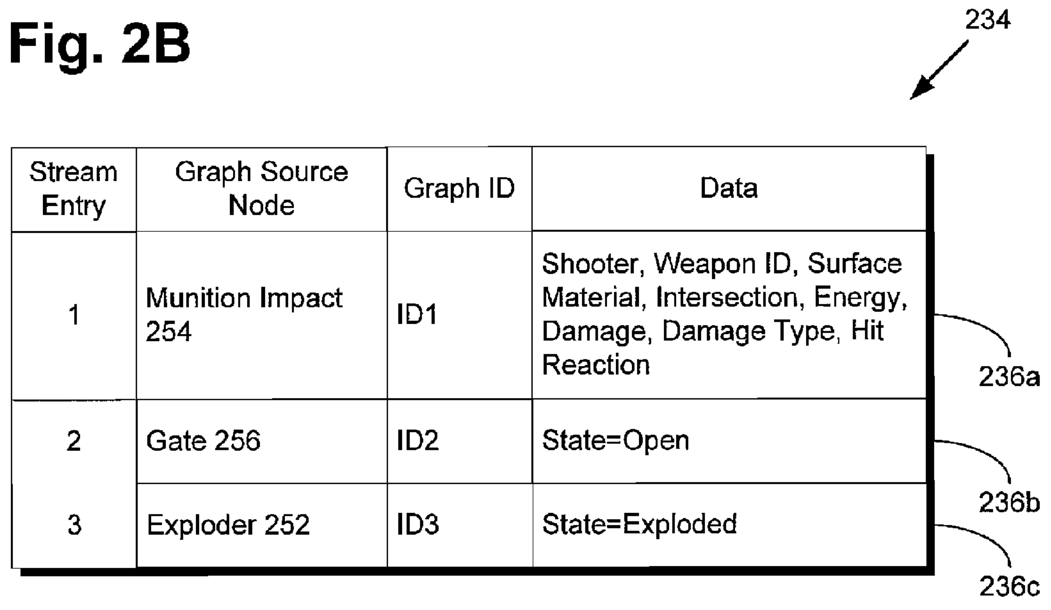

232a
Actor 250
Master
Destroyed●
Died●
Handle♦
Exploder 252
Master
●*Explode
Exploded●
♦Piece Base Velocity
♦Explosion Size Factor
♦Explosion Spread Factor
♦Weapon Hit Factor
♦Piece Randomness
♦Piece Lifetime
♦Collidable Piece Lifetime
Munition Impact 254
Master
Hit●
Shooter♦
Weapon ID♦
Surface Material♦
Intersection♦
Energy♦
Damage♦
Damage Type♦
Hit Reaction♦
Gate 256
●In
Master
Out●
●Open
●Close
Blocked●
●Toggle
Weapon Compare 258
●In
Master
True●
♦Weapon-A
False●
Report Stat 260
●Report
Master
♦StatIncrement
Out●
Shake Camera 262
●*In
Master
●*Shut off
♦Position
♦Inner Radius
♦Outer Radius
♦Amplitude
♦Speed
♦Duration
♦Rumble Type
Out●
Sound Effect 266
Master
Finished●
Playing●
End●
●*On
Begin●
Particle Effect 264
Master
●*On Transform
Out●

Fig. 2B


234
236a
236b
236c

Stream Entry	Graph Source Node	Graph ID	Data
1	Munition Impact 254	ID1	Shooter, Weapon ID, Surface Material, Intersection, Energy, Damage, Damage Type, Hit Reaction
2	Gate 256	ID2	State=Open
3	Exploder 252	ID3	State=Exploded

Fig. 2C

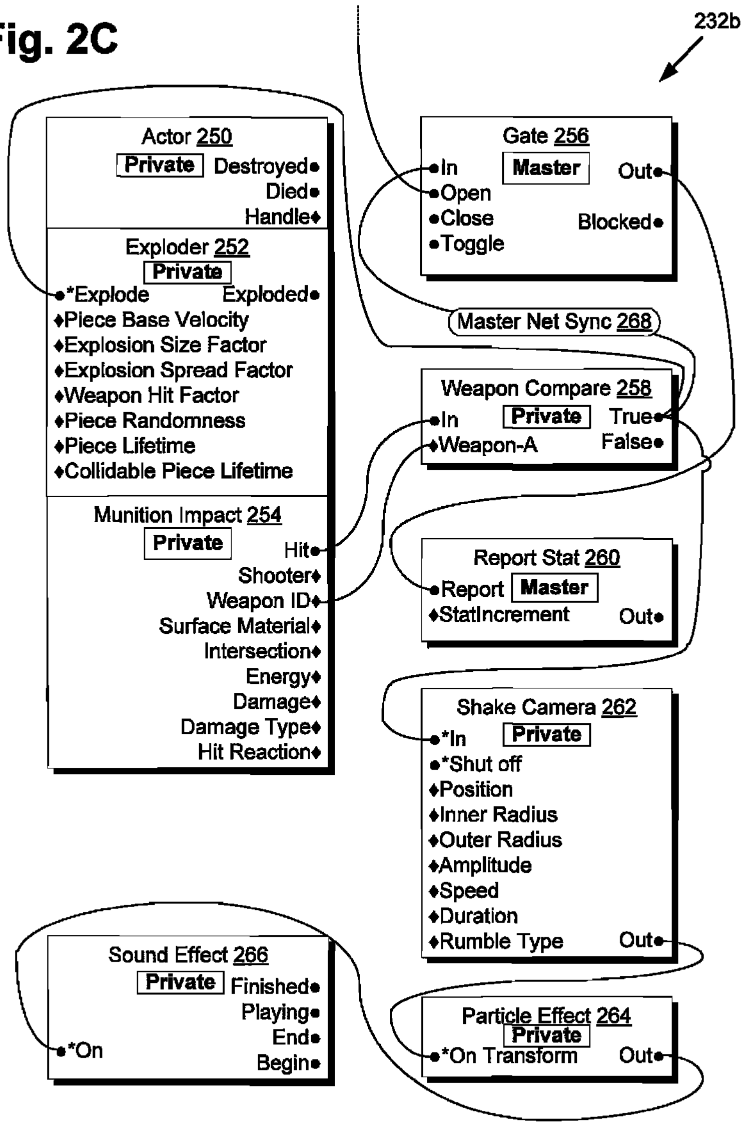

232b
Actor 250
Private
Destroyed●
Died●
Handle♦
Exploder 252
Private
●*Explode
Exploded●
♦Piece Base Velocity
♦Explosion Size Factor
♦Explosion Spread Factor
♦Weapon Hit Factor
♦Piece Randomness
♦Piece Lifetime
♦Collidable Piece Lifetime
Munition Impact 254
Private
Hit●
Shooter♦
Weapon ID♦
Surface Material♦
Intersection♦
Energy♦
Damage♦
Damage Type♦
Hit Reaction♦
Gate 256
●In
Master
Out●
●Open
●Close
Blocked●
●Toggle
Master Net Sync 268
Weapon Compare 258
●In
Private
True●
♦Weapon-A
False●
Report Stat 260
●Report
Master
♦StatIncrement
Out●
Shake Camera 262
●*In
Private
●*Shut off
♦Position
♦Inner Radius
♦Outer Radius
♦Amplitude
♦Speed
♦Duration
♦Rumble Type
Out●
Sound Effect 266
Private
Finished●
Playing●
●*On
End●
Begin●
Particle Effect 264
Private
●*On Transform
Out●

Fig. 2D

234a

Stream Entry	Graph Source Node	Graph ID	Data
1	Munition Impact 254	ID1	Shooter, Weapon ID, Surface Material, Intersection, Energy, Damage, Damage Type, Hit Reaction
2	Exploder 252	ID2	State=Exploded

236d

236e

234b

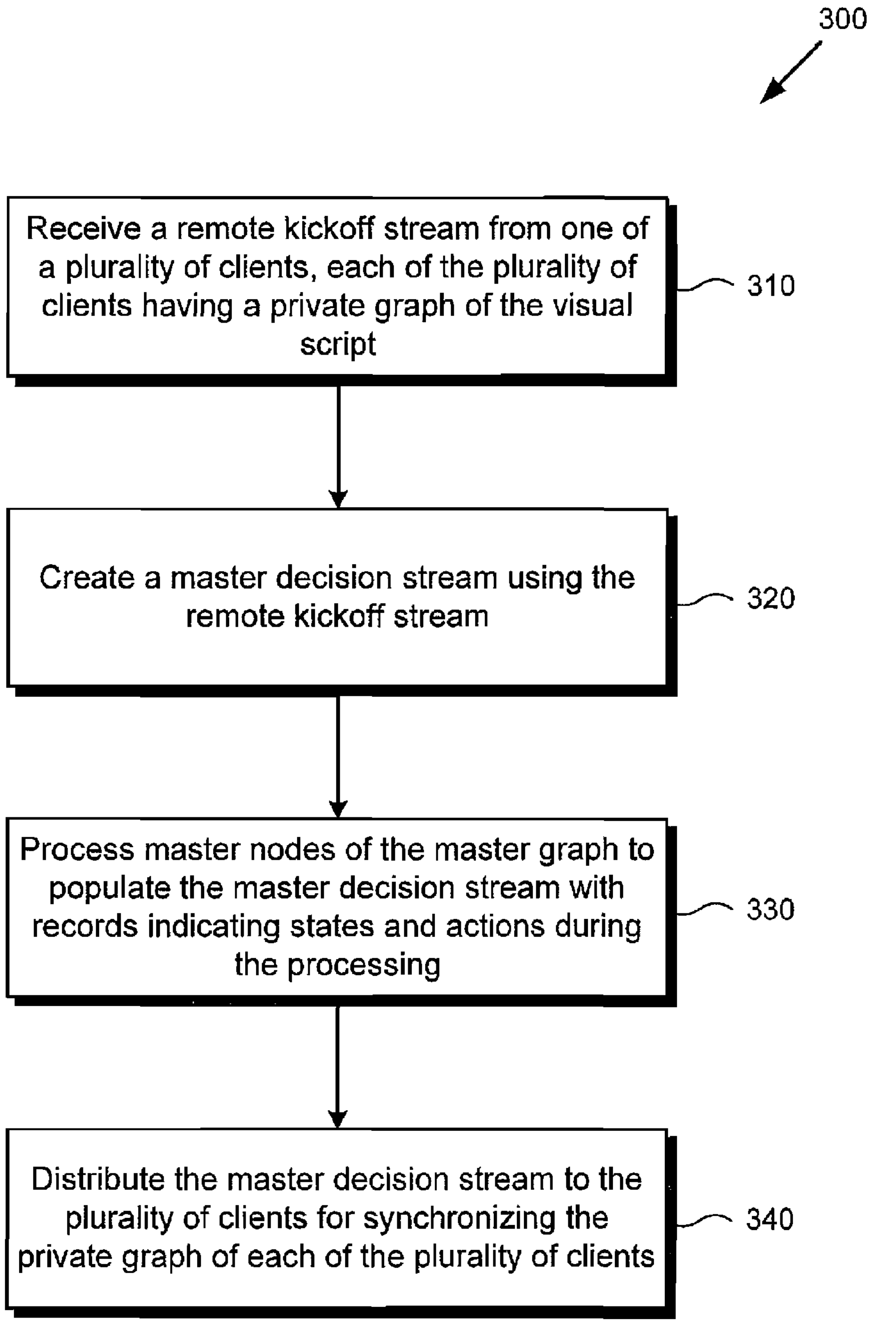
Stream Entry	Graph Source Node	Graph ID	Data
1	Master Net Sync 268	ID3	(Optional input parameters)
2	Gate 256	ID4	State=Open
3	Report Stat 260	ID5	-

236f

236g

236h

Fig. 3


300
Receive a remote kickoff stream from one of a plurality of clients, each of the plurality of clients having a private graph of the visual script
310
Create a master decision stream using the remote kickoff stream
320
Process master nodes of the master graph to populate the master decision stream with records indicating states and actions during the processing
330
Distribute the master decision stream to the plurality of clients for synchronizing the private graph of each of the plurality of clients
340

DECISION STREAMS FOR SYNCHRONIZING VISUAL SCRIPT LANGUAGE PROCESSING BETWEEN NETWORKED COMPUTERS

BACKGROUND

For certain applications, it is desirable to provide low latency synchronization of logic states between networked computers. This is especially important for real-time applications such as online video games, where near instant feedback is required for convincing interactivity. Additionally, to provide design flexibility and to modularize engine programming, it is desirable to control game logic using general-purpose scripting languages, especially visual scripting languages that are amenable to creation by graphical user interfaces (GUIs).

On the other hand, to keep logic states consistent between networked computers, it is also desirable to have a single arbiter for logic processing. For example, a networked multiplayer video game may need to determine a specific player to receive credit for defeating an enemy, or the video game may need to determine whether certain group-based or environmental prerequisites are satisfied before triggering an event. Conventionally, each networked computer may offload such game logic script processing to a centralized game server. However, due to the latency introduced by round trip network communications with the centralized game server, the goal of low latency state synchronization becomes more difficult to achieve.

SUMMARY

The present disclosure is directed to decision streams for synchronizing visual script language processing between networked computers, substantially as shown in and/or described in connection with at least one of the figures, as set forth more completely in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** presents an exemplary diagram of a system for providing decision streams for synchronizing visual script language processing between networked computers;

FIG. **2**A presents an exemplary diagram of a state graph expressed by a visual script language;

FIG. **2**B presents an exemplary diagram of a decision stream for synchronizing the state graph of FIG. **2**A between networked computers;

FIG. **2**C presents an exemplary diagram of a state graph expressed by a visual script language;

FIG. **2**D presents an exemplary diagram of decision streams for synchronizing the state graph of FIG. **2**C between networked computers;

FIG. **3** presents an exemplary flowchart illustrating a method by which decision streams may be provided for synchronizing visual script language processing between networked computers.

DETAILED DESCRIPTION

The following description contains specific information pertaining to implementations in the present disclosure. One skilled in the art will recognize that the present disclosure may be implemented in a manner different from that specifically discussed herein. The drawings in the present application and their accompanying detailed description are directed to merely exemplary implementations. Unless noted otherwise, like or corresponding elements among the figures may be indicated by like or corresponding reference numerals. Moreover, the drawings and illustrations in the present application are generally not to scale, and are not intended to correspond to actual relative dimensions.

FIG. **1** presents an exemplary diagram of a system for providing decision streams for synchronizing visual script language processing between networked computers. Diagram **100** of FIG. **1** includes client **110***a*, client **110***b*, server **120***a*, script database **130**, network **135**, display **140***a*, and display **140***b*. Client **110***a* includes processor **112***a* and memory **114***a*. Memory **114***a* includes game client application **116***a* and private graphs **118***a*. Client **110***b* includes processor **112***b* and memory **114***b*. Memory **114***b* includes game client application **116***b* and private graphs **118***b*. Server **120***a* includes processor **122***a* and memory **124***a*. Memory **124***a* includes game server application **126***a* and master graphs **128***a*. Script database **130** includes graph **132**.

Diagram **100** illustrates a simplified topology for an exemplary multi-player online videogame. Accordingly, only two clients **110***a*-**110***b* and one server **120***a* are shown. However, alternative implementations may support a much larger number of clients and may provide multiple servers for load balancing and/or reduced latency. Clients **110***a*-**110***b* and server **120***a* may be any computing device, such as a desktop computer, laptop computer, tablet, game console, or another device. Network **135** may be a public network such as the Internet, and may provide data links between clients **110***a*-**110***b*, server **120***a*, and script database **130**.

Furthermore, while a conventional server and client model is shown in diagram **100** of FIG. **1**, a peer-to-peer network may also be implemented, in which case all computing devices may be considered both clients and servers, as appropriate. Devices may form local peer-to-peer networks and distribute workloads based on user proximity within a virtual environment, with at least one computing device being dynamically designated as a "Master" computing device, corresponding to server **120***a*, for each peer-to-peer network. Devices may also participate in multiple peer-to-peer networks concurrently. For example, a device with a particularly high-speed and low-latency network connection may be preferably designated as a "Master" device for servicing multiple geographic areas of the virtual environment. The "Master" device handles the receiving and distributing of decision streams from other devices, as discussed in further detail below.

Script database **130** may be populated by several state graphs for implementing game logic, including graph **132** as shown. The graphs of script database **130** may be generated and edited using a visual script language creation tool, allowing game designers to script game logic using a graphical user interface (GUI). Alternatively, the graphs of script database **130** may also be provided using conventional text edited scripts.

In one particular arrangement of script database **130**, graphs may be sorted and divided according to associated locations within a virtual environment. Thus, clients **110***a*-**110***b* may retrieve the required graphs from script database **130** according to the in-game location of their particular character or avatar within their respective game client applications **116***a*-**116***b*. For example, when game client applications **116***a* and **116***b* include a respective avatar in a shared cave location, and when graph **132** is associated with the same cave location, a copy of graph **132** may be retrieved and stored within private graphs **118***a* and **118***b*.

Similarly, each online server may be assigned one or more locations to host, which may change dynamically to implement load balancing. Thus, server **120***a* may retrieve the required graphs from script database **130** based on the locations to be hosted by game server application **126***a*. For example, when server **120***a* is assigned to host the cave location, a copy of graph **132** may be retrieved and stored within master graphs **128***a*. If a large number of players enter the cave location, a new server may be assigned to also host the cave location. On the other hand, if a large number of players move to a different location, then server **120***a* may be reassigned to host the different location.

In a multi-player online game, it is desirable to maintain a high level of state synchronization between clients **110***a*-**110***b* so that all users can experience a coherent virtual environment, which is visually depicted on displays **140***a*-**140***b*. To provide this level of synchronization, clients **110***a*-**110***b* may send requests to server **120***a* to finally arbitrate any game logic affecting multiple clients. Thus, game client applications **116***a*-**116***b* may send requests to game server application **126***a* for evaluating multi-player game logic using master graphs **128***a*. However, since communications over network **135** may be subject to some unavoidable latency, the total time for receiving a response from server **120***a* may be significant, resulting in undesirable lag between user actions and the expected responses on displays **140***a*-**140***b*.

FIG. **2**A presents an exemplary diagram of a state graph expressed by a visual script language. Graph **232***a* of FIG. **2**A includes several nodes including actor **250**, exploder **252**, munition impact **254**, gate **256**, weapon compare **258**, report stat **260**, shake camera **262**, particle effect **264**, and sound effect **266**. With respect to FIG. **2**A, graph **232***a* may correspond to graph **132** in FIG. **1**.

As shown in FIG. **2**A, graph **232***a* is organized in a visual layout with several interconnected nodes for evaluating game logic. Nodes may process one or more input functions, which are labeled with circles aligned to the left side of each node. Certain nodes, such as munition impact **254**, may be considered a "kickoff node" that can execute an anonymous function without being triggered by an external input. After function execution, nodes may also fire one or more output impulses, which are labeled with circles aligned to the right side of each node. These output impulses may surge through graph **232***a* to trigger input functions of downstream nodes, and may be connected to multiple downstream nodes, as shown in gate **256**. Further, each node may contain one or more parameters, indicated by diamonds, which may be passed between nodes. The specific function logic of each node is omitted for simplicity but may be inferred from the node title and the inputs and outputs shown.

Graph **232***a* may represent a game scenario where actor **250** is exploded by a munition impact **254** only when gate **256** is set to the "Open" state, which is controlled by some external logic, not shown in FIG. **2**A. For example, a player character controlled by client **110***a* may attempt to attack actor **250**, which triggers the munition impact **254** kick-off node for client **110***a*. At the time of impact, client **110***a* may populate all the required parameters in munition impact **254** and send the "Hit" output impulse to the "In" input function of weapon compare **258**, with "Weapon ID" passed as a parameter.

Moving to the next node, weapon compare **258** executes logic for the "In" input function, comparing "Weapon ID" with "Weapon-A", which may be set to a specific weapon ID, for example a shoulder charge. If the comparison is true, the "True" output impulse is fired as shown; otherwise, the "False" output impulse is fired.

Next, gate **256** executes logic for the "In" input function. As shown in graph **232***a*, the "Open" input function is triggered by another node that is not shown. After executing the

"Open" input function, gate **256** may set an internal state indicating an open status. The "In" input function may confirm that the internal state is set to "open" before sending an "Out" output impulse. Otherwise, if the internal state is set to "closed", the "Blocked" output impulse may be fired instead. As shown in FIG. **2**A, the "Out" output impulse is connected to multiple nodes, or exploder **252** and report stat **260**. When multiple output impulses are emitted and the branches are independent of each other, the downstream node branches may be processed serially in any order or alternatively in parallel. Otherwise, the branches may be traversed serially according to data dependencies.

Assuming exploder **252** is the first node to be processed, the "Explode" input function is triggered using various parameters, as listed. Since no additional output impulses are fired at exploder **252**, processing may proceed to nodes of the next branch, beginning with report stat **260**.

At report stat **260**, the "Report" input function may record the details of munition impact **254**, for example by writing a record in a database. The database may then be consulted by the videogame to determine whether enough damage has been inflicted on actor **250** to trigger an output impulse, and also to determine the distribution of experience points, money, and other rewards. After the recording, the "Out" output impulse is fired, triggering the "In" input function of shake camera **262**.

Shake camera **262** may then provide a camera shaking effect to the view of display **140***a* and **140***b* in FIG. **1** according to the various parameters as shown. Shake camera **262** may also fire the "Out" output impulse to trigger the "On Transform" input function of particle effect **264**, which may apply particle effects to the explosion in progress triggered by exploder **252**. The "Out" impulse of particle effect **264** in turn triggers the "On" input function of sound effect **266**, which may play an explosion sound effect on display **140***a* of client **110***a*. At this point, since sound effect **266** has no further output impulses, processing of the second and final branch ends. If additional effects and processing are required, they may be triggered from the "Begin" output impulse of sound effect **266**.

Referring back to FIG. **1**, as previously discussed, a copy of graph **132** corresponding to graph **232***a* of FIG. **2**A may be copied and locally stored in private graphs **118***a*, private graphs **118***b*, and master graphs **128***a*. Thus, client **110***a* and client **110***b* may have independent graph states that can differ from each other as they are privately processed, leading to inconsistent game states between clients. To keep graphs synchronized, all state processing might be deferred to master graphs **128***a* on server **120***a*. However, since each client must wait for a response from server **120***a* over network **135**, large latency penalties may result, reducing game responsiveness and detracting from gameplay.

Accordingly, FIG. **2**B presents an exemplary diagram of a decision stream for synchronizing the state graph of FIG. **2**A between networked computers. Decision stream **234** includes record **236***a*, record **236***b*, and record **236***c*. Each of records **236***a*-**236***c* includes a stream entry field, a graph source node field, a graph ID field, and a data field.

Decision stream **234** is a record of states and actions taken based on those states. By creating and distributing decision stream **234**, other networked computers can follow a single authoritative course of action to remain synchronized with each other. The creation of a decision stream begins when a kick-off node is processed. By default, a kick-off node may be marked as a "Master" node requiring global synchronization. In this case, if a kick-off node is processed at a local client, the local client only generates a KickoffStream that contains data regarding the specific event at the kick-off node, which may also be considered as a special case single-entry decision stream. Output impulses and surges that would be normally fired are not fired; instead, the Kickoff Stream is passed as a Remote Kickoff Stream to a Graph Master, for example server **120***a*, which can then handle the creation of the actual decision stream **234**. A Kickoff callback function is also registered for each client to handle the processing of decision stream **234** when eventually received from network **135**.

Once server **120***a* receives the Remote Kickoff Stream from client **110***a*, server **120***a* can begin the actual process of generating decision stream **234**. First, as shown in record **236***a*, the details from the Remote Kickoff Stream are simply copied over to decision stream **234**. The "stream entry" field enumerates the record and may indicate the desired order of processing. The "graph source node" field references the munition impact **254** node from graph **132**, corresponding to graph **232***a*. The "graph ID" field "ID1" may more specifically refer to the particular node within master graphs **128***a*. Note that while at a minimum, only the first record needs to have a graph ID as the graph ID of the remaining records may be traced and derived from the first record, for ease of debugging and tracing it may be preferable to record the graph ID for each record in decision stream **234**. The "data" field contains all the parameters in munition impact **254**.

After writing record **236***a*, server **120***a* may continue processing graph **232***a* within master graphs **128***a*, adding new records to decision stream **234** as necessary. Thus, the processing of graph **232***a* continues as the parameters from munition impact **254** are examined and a "Hit" output impulse is accordingly sent to weapon compare **258**. Since the processing of weapon compare **258** is entirely dependent on inputs and does not use any internal states, no records need to be written to decision stream **234** regarding weapon compare **258**.

Continuing to gate **256**, the processing of gate **256** on the other hand requires a determination of the internal state of the gate, or whether it is open or closed. Moreover, the state of gate **256** may be independently affected by various clients. Accordingly, record **236***b* is written to decision stream **234** as shown, with the state of gate **256** recorded as open. Since the gate state is open, a output impulse is sent to exploder **252** and report stat **260**. For exploder **252**, record **236***c* is written to decision stream **234** as shown, reflecting the state of exploder **252**. This is necessary since the explosion state may differ between machines due to latency.

On the other hand, for the node branch starting with report stat **260**, no further records are required as none of the remaining nodes require synchronization. For example, report stat **260** only requires writing a single record in a database without any synchronization, and shake camera **262**, particle effect **264**, and sound effect **266** all relate to audiovisual effects that can be locally processed by each client without synchronization. Optionally, a "private net sync" node may be explicitly inserted after report stat **260** to indicate that the remaining nodes are to be processed locally on private graphs. Accordingly, after reaching sound effect **266** or the private net sync node, decision stream **234** may be finalized and sent back via network **135** to all clients participating in the same game, including client **110***a* and client **110***b*.

As discussed previously, each client may have a callback function to handle the processing of decision stream **234** after being received from network **135**. The callback function will mirror the processing of the relevant graph in the locally stored graph, or a graph within private graphs **118***a* and **118***b* for clients **110***a* and **110***b* respectively. If node states are inconsistent between the local graph and decision stream **234**,

the recorded states in decision stream **234** override the local graph, thereby enforcing synchronization.

While graph **232***a* may be synchronized using decision stream **234**, the latency result is suboptimal as much of the same waiting time for server synchronization still occurs when the kick-off node munition impact **254** is set to global synchronization or "master" as per default settings for graph **232***a*. While this default setting allows game designers to create logic graphs without having to consider synchronization, manual or automated assignment of synchronization settings to nodes also enables game designers to greatly optimize game logic for minimal latency. Individual nodes may be explicitly set to "private", which do not require synchronization, or "master", which require global synchronization. Modifier nodes, such as master net sync or private net sync nodes, may also explicitly set the synchronization setting for all downstream nodes. By identifying certain nodes as private, these nodes can be processed locally and immediately at each client for reduced latency.

Thus, turning to FIG. **2**C, FIG. **2**C presents an exemplary diagram of a state graph expressed by a visual script language. With respect to FIG. **2**C, like numbers may correspond to like elements from FIG. **2**A. FIG. **2**C also includes an additional node not present in FIG. **2**A, master net sync **268**.

As shown in FIG. **2**C, graph **232***b* is modified from graph **232***a* such that munition impact **254** is set to "private" rather than the default "master". Additionally, master net sync **268** is inserted prior to gate **256**, the output impulses from gate **256** to exploder **252** and report stat **260** are transferred to weapon compare **258**, and the output impulse from report stat **260** to shake camera **262** is transferred to weapon compare **258**. Accordingly, gate **256** and report stat **260** are set to "master", whereas all other nodes are set to "private".

Since the kick-off node or munition impact **254** is set to "private", client **110***a* can take control and proceed to process its own copy of graph **232***b* within private graphs **118***a*, rather than immediately sending a kick-off stream to a server. Thus, client **110***a* can process graph **232***b* and generate a private decision stream, at least for those nodes that are set to "private". Accordingly, munition impact **254**, weapon compare **258**, exploder **252**, shake camera **262**, particle effect **264**, and sound effect **266** can all be processed and evaluated on client **110***a* without consulting or synchronizing with any outside clients or servers.

The resulting decision stream is shown as private decision stream **234***a* of FIG. **2**D, which presents an exemplary diagram of decision streams for synchronizing the state graph of FIG. **2**C between networked computers. As shown in private decision stream **234***a*, client **110***a* only records entries **236***d* and **236***e* for munition impact **254** and exploder **252**, similar to the processing of graph **232***a* by server **110***a* as discussed above. However, once processing on all private nodes is completed, nodes beyond master net sync **268** must be processed on server **120***a*, as these downstream nodes are set to "master" requiring global synchronization.

Accordingly, prior to handing processing control to server **110***a*, private decision stream **234***a* may be sent to server **120***a*, which may be used to synchronize master graphs **128***a*. To synchronize the private graphs on the remaining clients, server **120***a* may distribute private decision stream **234***a* to the other clients in the same game, including client **110***b*, so that all clients can carry out the same actions as indicated in private decision stream **234***a*. Advantageously, near instantaneous feedback is provided in response to user actions on the client where the kick-off node originated, or client **110***a*, since client **110***a* can process private nodes directly without waiting for a decision stream from an outside source. Thus, the user of client **110***a* can appreciate immediate visual and audio effects from a user initiated weapon attack. While other clients such as client **110***b* may render a slightly delayed response since synchronization starts upon receiving private decision stream **234***a*, the delayed response may be acceptable since the effects are concerning the actions of other users rather than the specific user of the client.

After server **120***a* distributes private decision stream **234***a*, server **120***a* may begin the process of building its own master decision stream **234***b* for the remaining downstream nodes set to master, or global synchronization. As shown in FIG. **2**D, master decision stream **234***b* includes records **236***f*, **236***g*, and **236***h*. The stream building process may proceed similar to the processing of graph **232***a* by server **120***a*, as described above. However, master net sync **268** rather than munition impact **254** triggers the creation of the remote kickoff stream, and only the "Master" nodes of graph **232***b* are processed. Accordingly, a record **236***f* for master net sync **268** may be created as shown, which may include any optional input parameters that are necessary for downstream node processing. In the case of graph **232***b*, since only the "True" output impulse is sent to master net sync **268** from weapon compare **258**, no parameters are necessary in the data field of record **236***f*. Record **236***g* may be added to record the state of gate **256**. Record **236***h* may be added with an empty data field to simply indicate that the report stat **260** node was processed successfully, as the report stat **260** node may write a record into a database which has its own synchronization facilities.

Server **120***a* may distribute the completed master decision stream **234***b* to all relevant clients, including client **110***a* and **110***b*, for final synchronization. For record **236***g*, each client may update in their respective private graphs the state of gate **256** to "open" as indicated in the data field. For record **236***h*, since the data field is empty, each client may independently query the relevant values from the database used by report stat **260** to calculate total damage inflicted on actor **250**. After distributing and processing master decision stream **234***b* for each client, all processing and network synchronization of graph **232***b* originating from the munition impact **254** kickoff node is completed. Accordingly, processing of graph **232***b* is done with reduced latency for high responsiveness to user inputs while maintaining synchronization of important multiplayer logic such as accurate distribution of in-game rewards.

FIG. **3** presents an exemplary flowchart illustrating a method by which decision streams may be provided for synchronizing visual script language processing between networked computers. Flowchart **300** begins when processor **122***a* of server **120***a* receives, over network **135**, a remote kickoff stream from client **110***a*, where client **110***a* and client **110***b* each have a private graph of graph **132** in private graphs **118***a* and **118***b*, respectively (block **310**). As discussed above, a remote kickoff stream may begin when a kickoff node is triggered on a local or private graph, or when a master net sync node is encountered while processing a private graph. Thus, the remote kickoff stream may contain a record for the details of the kickoff node, similar to record **236***a*, or a record for the details of the master net sync node, similar to record **236***f*.

When graph **132** corresponds to graph **232***b*, where the kick-off node munition impact **254** has additional private nodes connected, a private decision stream may be created at the client where the kick-off node originally triggered, or client **110***a*. Thus, prior to receiving the remote kickoff stream, processor **122***a* of server **120***a* may also receive, synchronize, and distribute private decision stream **234***a*. More specifically, processor **122***a* of server **120***a* may receive private decision stream **234***a* from client **110***a* over network **135**, synchronize master graphs **128***a* using private decision stream **234***a*, and distribute private decision stream **234***a* to the remaining clients over network **135** to synchronize the other private graphs. In this case, the distributing of private decision stream **234***a* would only be to client **110***b* to update private graphs **118***b*. As previously discussed, a callback function may be registered at each client to handle the receiving of private and master decision streams for synchronizing.

Next, processor **122***a* of server **120***a* creates a master decision stream using the remote kickoff stream (block **320**). If the remote kickoff stream contains a record similar to record **236***a*, then the master decision stream may appear similar to decision stream **234** of FIG. **2**B, with only record **236***a* populated. If the remote kickoff stream contains a record similar to record **236***f*, then the master decision stream may appear similar to master decision stream **234***b* of FIG. **2**D, with only record **236***f* populated. Accordingly, the creation of the master decision stream may simply copy the records present in the provided remote kickoff stream.

Next, processor **122***a* of server **120***a* processes master nodes of the master graph to populate the master decision stream with records indicating states and actions during the processing (block **330**). Assuming graph **132** corresponds to graph **232***b*, processor **122***a* of server **120***a* may process those nodes marked as "master" in graph **232***b*, or gate **256** and remote stat **260**. Thus, master decision stream **234***b* may be populated with records **236***g* and **236***h* to indicate the states and actions taken during the processing of gate **256** and report stat **260**, respectively.

Next, processor **122***a* of server **120***a* distributes the master decision stream to clients **110***a* and **110***b* for synchronizing private graphs **118***a* and **118***b* (block **340**). As previously discussed, a callback function may be registered at each client to receive the master decision stream **234***b* and update the private graphs, which may be processed in an identical fashion at each respective client. Accordingly, each client is updated using a single authoritative master decision stream **234***b*.

In addition to providing synchronization between networked computers, the decision streams may also be used as a general purpose networked data distribution system, as any data may be included as records in the decision stream. Thus, for example, decision streams may be utilized to allow new players to join an existing multi-player game session by including records having all of the relevant game states that would require updating on the client of the new player.

From the above description it is manifest that various techniques can be used for implementing the concepts described in the present application without departing from the scope of those concepts. Moreover, while the concepts have been described with specific reference to certain implementations, a person of ordinary skill in the art would recognize that changes can be made in form and detail without departing from the spirit and the scope of those concepts. As such, the described implementations are to be considered in all respects as illustrative and not restrictive. It should also be understood that the present application is not limited to the particular implementations described herein, but many rearrangements, modifications, and substitutions are possible without departing from the scope of the present disclosure.

What is claimed is:

1. A computing device for providing decision streams for synchronizing visual script language processing between networked computers, the computing device comprising:

a memory including a game application and a master graph of a visual script, wherein the master graph includes a plurality of nodes, each of the plurality of nodes having a synchronization setting being set to private or master;

a processor configured to execute the game application to:

receive a remote kickoff stream from one of a plurality of clients, each of the plurality of clients having a private graph of the visual script, wherein the private graph specifies an in-game location of a corresponding client of the plurality of clients, and wherein the remote kickoff stream contains data regarding a specific triggered event and is generated for processing the specific triggered event;

create a master decision stream using the remote kickoff stream, wherein the master decision stream is created for utilization by the plurality of clients to synchronize with each other;

process master nodes of the master graph to populate the master decision stream with records indicating states and actions during the processing, wherein the master nodes are specified as requiring global synchronization and utilization by the plurality of clients to enforce synchronization by overriding the private graph of the corresponding client of the plurality of clients;

process a private net sync node of the master graph, wherein the private net sync node sets the synchronization setting for one or more of the plurality of nodes to be private to specify that the one or more nodes do not require synchronization, and wherein the processing of the private net sync node mirrors a processing performed by at least one of the plurality of clients without consulting or synchronizing with other one or more of the plurality of clients;

finalize, in response to processing the private net sync node, the master decision stream; and

distribute, after finalizing, the master decision stream to the plurality of clients for synchronizing the private graph of each of the plurality of clients in response to processing the private net sync node of the master graph, wherein the master graph is for global synchronization of the private graphs of the plurality of clients.

2. The computing device of claim **1**, wherein the remote kickoff stream contains a record for a kick-off node.

3. The computing device of claim **1**, wherein the remote kickoff stream contains a record for a master net sync node.

4. The computing device of claim **1**, wherein prior to receiving the remote kickoff stream, the processor is further configured to:

receive a private decision stream from the one of the plurality of clients;

synchronize the master graph using the private decision stream; and

distribute the private decision stream to the plurality of clients for synchronizing the private graph of each of the plurality of clients.

5. The computing device of claim **1**, wherein the visual script is editable using a visual script language creation tool allowing scripting of game logic using a graphical user interface (GUI).

6. The computing device of claim **1**, wherein the visual script is retrieved from a script database based on the in-game location of a corresponding client of the plurality of clients.

7. The computing device of claim **1**, wherein the distributing of the master decision stream is received by a callback function registered at each of the plurality of clients.

8. A method for use by a game server for providing decision streams for synchronizing visual script language processing between networked computers, the method comprising:

receiving, by the game server, a remote kickoff stream from one of a plurality of clients, each of the plurality of clients having a private graph of a visual script, wherein the private graph specifies an in-game location of a corresponding client of the plurality of clients, and wherein the remote kickoff stream contains data regarding a specific triggered event and is generated for processing the specific triggered event;

creating, by the game server, a master decision stream using the remote kickoff stream, wherein the master decision stream is created for utilization by the plurality of clients to synchronize with each other;

processing, by the game server, master nodes of a master graph of the visual script to populate the master decision stream with records indicating states and actions during the processing, wherein the master graph includes a plurality of nodes, each of the plurality of nodes having a synchronization setting being set to private or master, wherein the master nodes are specified as requiring global synchronization and utilization by the plurality of clients to enforce synchronization by overriding the private graph of the corresponding client of the plurality of clients;

processing, by the game server, a private net sync node of the master graph, wherein the private net sync node sets the synchronization setting for one or more of the plurality of nodes to be private to specify that the one or more nodes do not require synchronization, and wherein the processing of the private net sync node mirrors a processing performed by at least one of the plurality of clients without consulting or synchronizing with other one or more of the plurality of clients;

finalizing, by the game server, in response to the processing of the private net sync node, the master decision stream, wherein the private net sync node sets the synchronization setting for one or more of the plurality of nodes to be private; and

distributing, by the game server, after the finalizing, the master decision stream to the plurality of clients for synchronizing the private graph of each of the plurality of clients in response to the processing of the private net sync node of the master graph, wherein the master graph is for global synchronization of the private graphs of the plurality of clients.

9. The method of claim **8**, wherein the remote kickoff stream contains a record for a kick-off node.

10. The method of claim **8**, wherein the remote kickoff stream contains a record for a master net sync node.

11. The method of claim **8** further comprising, prior to receiving the remote kickoff stream:

receiving a private decision stream from the one of the plurality of clients;

synchronizing the master graph using the private decision stream; and

distributing the private decision stream to the plurality of clients for synchronizing the private graph of each of the plurality of clients.

12. The method of claim **8**, wherein the visual script is editable using a visual script language creation tool allowing scripting of game logic using a graphical user interface (GUI).

13. The method of claim **8**, wherein the visual script is retrieved from a script database based on the in-game location of a corresponding client of the plurality of clients.

14. The method of claim **8**, wherein the distributing of the master decision stream is received by a callback function registered at each of the plurality of clients.

15. A system for providing decision streams for synchronizing visual script language processing between networked computers, the system comprising:

a plurality of clients each having a private graph of a visual script, wherein the private graph specifies an in-game location of a corresponding client of the plurality of clients, and wherein the remote kickoff stream contains data regarding a specific triggered event and is generated for processing the specific triggered event;

a network;

a master computing device comprising:

a memory including a game application and a master graph of the visual script, wherein the master graph includes a plurality of nodes, each of the plurality of nodes having a synchronization setting being set to private or master;

a processor configured to execute the game application to:

receive, over the network, a remote kickoff stream from one of the plurality of clients;

create a master decision stream using the remote kickoff stream, wherein the master decision stream is created for utilization by the plurality of clients to synchronize with each other;

process master nodes of the master graph to populate the master decision stream with records indicating states and actions during the processing, wherein the master nodes are specified as requiring global synchronization and utilization by the plurality of clients to enforce synchronization by overriding the private graph of the corresponding client of the plurality of clients;

process a private net sync node of the master graph, wherein the private net sync node sets the synchronization setting for one or more of the plurality of nodes to be private to specify that the one or more nodes do not require synchronization, and wherein the processing of the private net sync node mirrors a processing performed by at least one of the plurality of clients without consulting or synchronizing with other one or more of the plurality of clients;

finalize, in response to processing the private net sync node, the master decision stream; and

distribute, after finalizing, over the network, the master decision stream to the plurality of clients for synchronizing the private graph of each of the plurality of clients in response to processing the private net sync node of the master graph, wherein the master graph is for global synchronization of the private graphs of the plurality of clients.

16. The system of claim **15**, wherein the remote kickoff stream contains a record for a kick-off node.

17. The system of claim **15**, wherein the remote kickoff stream contains a record for a master net sync node.

18. The system of claim **15**, wherein prior to receiving the remote kickoff stream, the processor is further configured to:

receive, over the network, a private decision stream from the one of the plurality of clients;

synchronize the master graph using the private decision stream; and

distribute, over the network, the private decision stream to the plurality of clients for synchronizing the private graph of each of the plurality of clients.

19. The system of claim **15**, wherein the visual script is editable using a visual script language creation tool allowing scripting of game logic using a graphical user interface (GUI).

20. The system of claim **15**, wherein the visual script is retrieved from a script database based on the in-game location of a corresponding client of the plurality of clients.

* * * * *